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ABSTRACT

Management of the innovation process is described, and resources on which innovation management must operate are identified. The relationship of information to subsystems in the innovation process is examined using empirical results from sociology, communication, and psychology. Analysis develops from a one-man information model, through a two-person and a national system, to a general information system and network. Implications for management of innovation conclude the presentation. (CH)

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MANAGEMENT OF INNOVATION: THE ROLE OF COMMUNICATION

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Management of innovation. The role of communication.

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Man is differentiated from all other creatures by his ability to conceive of new goals, to select from among them, and to create the social mechanism and technologies for achieving the goals selected.
The process of creating and using the results of man's creative efforts has, over the past few years, been described and discussed under the heading of "innovation", which is an omnibus word that is used rather imprecisely.

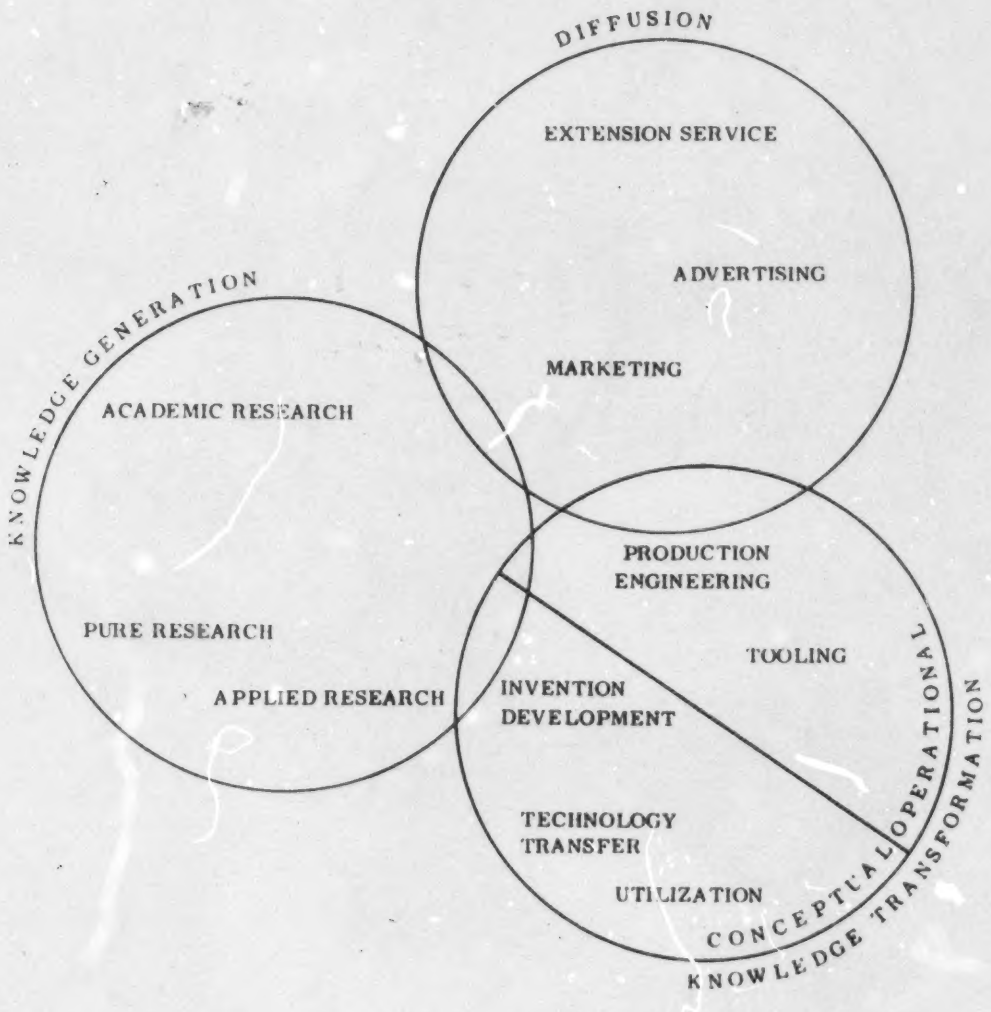
To avoid some of the confusion that marks the literature on the subject I have chosen to try to define "innovation" in a way that includes the sense, in which it is used by serious scholars in the field as well as the way it is used here to mean the overall process by which invention is brought into being and into successful use by potential users.
The innovation process includes three major and overlapping subprocesses: generation, transformation and diffusion (See Figure 1).
As can be seen in the chart, the overall innovation process consists of three major overlapping subsystems or subprocesses: the knowledge generation subsystems, the knowledge transformation subsystems and the innovation diffusion subsystem.

The knowledge generation subsystem
The knowledge generation subsystem is concerned with the generation, storage and circulation of new knowledge. It includes, as far as we know, universities, institutes, laboratories, scientific societies, libraries and the scientific and technical publishing establishment. It includes academic research, pure research, applied research.

The transformation subsystem is devoted to the conceptual and operational transformation of knowledge to use. To bring some collection of knowledge to bear on a problem, opportunity or need almost always requires some transformation from idea to device; from one form of use to another. The subsystem includes development, technology transfer (transfer from use in one context to use in another), technology utilization (transfer from one intended use to another). An innovation must usually go through a final transformation into a form that can be produced and marketed. Thus the transformation system includes such functions as production engineering and tooling.

The diffusion subsystem is a cohesive and coherent follow-on of the transformation subsystem. The diffusion subsystem includes marketing institutions and extension service and also includes a variety of information distribution systems that may or may not be directly connected with marketing in its broadest sense (e.g. advertising, fairs, exhibits).

Management of the innovation process
Management of the innovation process, then, is the conscious, deliberate, intelligent manipulation of resources and conditions to achieve and control the type, quality and quantity of innovation desired. (Control of the innovation process does not only mean obtaining more innovation more rapidly. It also means achieving a desirable decrease in such harmful innovations as dangerous drugs).
Management means the ability to apply our resources and energies to the three subprocesses I have just described, so that we get what we want in terms of utility at the end-point of the process. The management of innovation includes a large spectrum of activities from the management of academic research to the conduct of industrial fairs. It



THE INNOVATION PROCESS

starts with trying to generate more and better research results or knowledge more effectively and efficiently. It continues with the management of direction, quality and quantity of development and technology transfer, and proceeds through efforts to increase the rate and quantity of acceptance of an innovation by the final users.

Government and industry are interested in many parts of the entire process. It is clear that industry has a vital interest in improving the ability to manage innovation since it is interested in obtaining and maintaining a competitive position in the marketplace. Industry wants new or improved products, new processes that lower costs and prices and new means for providing improved service. Government has a vital interest in managing the innovation process in the interest of improving the social, economic and political position and condition of the nation. Government is interested in innovation for such things as increasing productivity, improving the economy, attaining better health and welfare for its citizens and achieving military security. Today, governments are particularly interested in trying to obtain the transformation of their large investments in research and development, to get more utility from the knowledge produced to date.

Unfortunately, despite a strong public interest in innovation, science and technology there is only a limited amount of empirical information available that is directly applicable to the intelligent management of the innovation process; and if I may be permitted a critical comment, what we have available is not known or is ignored by those who could use it.

I hope you noted, as I did with some interest, that both Professor Freeman and Professor Holt very carefully pointed to the empirical evidence, and I will follow the same approach. The reason we emphasize the data is that we suffer from a pollution in discussions of innovation. The sources of contamination are often the experienced, accomplished, scientists and engineers, who having been successful practitioners, think they can speak authoritatively about the innovation process with no more data than a datum point of one - their own experience.
I would propose that the experience of one man, a single point, is a poor basis upon which to draw a curve.

Two sets of resources are central to every part of the innovation process: people and information, and it is these two sets that are the "materials" which innovation management must operate upon to have any effect on the process. Since people are the producers, adopters and users of innovation their role is obvious and there is a large and familiar literature on creativity, organizational behaviour, social, industrial and marketing psychology that discusses the recruiting, motivating, educating and general treatment of the human in the innovative context.

Not so familiar, and not so well treated, is the importance of information in every part of the process. In one sense, we can make a good case for saying that the management of innovation is the management of information since research and development is really a process of transforming information from one state to another, transformation is an information matching process, and diffusion is certainly a specific communications problems in which we wish to elicit certain behaviors on the part of the receivers of the information that we are transmitting concerning an innovation. The communication of information is the process of transmitting the information from some source to some receiver, and it is the process of communication of the information we loosely identify as knowledge that I want to discuss in some detail.
In the rest of my paper I will discuss some of the relationship of information to each of the three major sub-areas in the innovation process drawing upon available results obtained from a large number of empirical studies from such diverse fields of enquiry as rural and medical sociology, information behavior amongst scientists and engineers, mass communications, the psychology of attitude change, propaganda, diffusion and innovations economics and the history of science and technology. The discussion will be in terms of a one man information system, a two person system, a national and, final-

ly a general information system.
I will examine some of the implications for management of innovation that can be developed from the available information.

The One-Person Information System

The fundamental building block of an information system is the one-person information system. I will discuss the one-person system in terms of man's observed behavior when dealing with the communication of information, and not in terms of his internal psychological makeup. To understand, design, or manage any part of the information behavior relevant to the innovation process we really have to understand something of the way the individual scientist, engineer and manager obtains and uses information; the sources he tends to use, the channels he prefers, the amount of time he spends communicating and the differences between individuals with regard to information communication behavior. Fig. 2 indicates some of the parameters that have been used in emperical studies of information behavior.

Extent of communication and relationship to productivity — First, it is important to know to what extent communication occupies the working life of people engaged in the innovation process. Studies of how scientists, engineers, general and production managers spend their time all indicate that more time is spent in communicating at business, scientific, personal and social levels than all other professional activities combined. In a study of chemists it was found that the average time spent in communication was well over 50% of their working time (33.4% in scientific communication, 10.4% in business communication and over 9% on personal and social communications).

In a series of studies of scientists and engineers in organizations (Pelz and Andrews, 1966) it was found that productivity (as measured by publication of articles, reports and the opinions of peers and supervisors) was generally correlated with frequency of communication with colleagues and outsiders as well as with the number of people communicated with regularly. The more people regularly communicated with and the more frequent the communications the more productivity. The only measure that sometimes went down with frequency of communication was journal article publication. Another study found that journal article production was correlated with the amount of reading done. The more a man reads the more articles he is likely to produce or vice versa.

The idea that a great deal of informal communication is related to productivity goes contrary to the views of traditional managers who have drawn their views from the classical, mass-production ethic. The idea that the coffee or tea break is as important as any activity in the laboratory is difficult for many old line managers to digest. As one man laughingly told me at a seminar in Düsseldorf, his boss agreed that the coffee break was important. He thought that it was so important that he had coffee delivered to every desk so that it would not be interrupted by useless conversation with others.

Sources and channels of information — When examining the use of formal literature, as might be expected, it is found to vary with work situation. Pure scientists make greater use of published materials (75%) than applied scientists (50%). Engineers make almost no use of the so called "good" scientific literature found in the journals. Engineers primarily use handbooks, manufacturers' catalogues, reprints, standards, specifications and research reports. Earlier, when Professor Holt pointed out that engineers do not read the scientific literature, he humorously stated that some people claim that engineers must be taught to read or should be provided with more time to read. I propose that the answer may be that the scientific literature is generally of no use to the engineer.

When the reading behavior of scientists has been compared with that of technologists it has been found that scientists are much more restricted to a narrow band, area-of-work reading interest while technologists browse more, search many areas and read in fields that are peripheral or marginally related to their apparent center of concentra-

Figure 2

The One Person Information System

A. Information	B. Sources	C. Channels	D. Situations	E. Individuals
1. Quantity	1. People	1. Formal	1. Nature of work Pure (R) apolied (D) Mgt	1. Capacity
2. Diversity	2. Records	2. Informal	2. Nature of need logistic nutritive	2. Capability
	3. Personal Experience		3. Work setting physical organizational	3. Demographics
				4. Motivation

tion. Technologists or engineers, interested in solving a problem or generating a design that functions are interested in finding any information that will help them with the task at hand. Therefore they are constantly scanning a variety of sources and particularly sources with immediate application to the problem at hand. Scientists are far narrower and deeper in their literature needs, essentially consuming articles as one form of input to the production of new journal articles. The very low use of journal articles by engineers and technologists raises a serious question as to the wisdom of the current and proposed expenditures on expensive computerized retrieval systems to make available to engineers information which they do not use.

As has already been suggested, oral channels, or word of mouth, play a very important place in information behavior in the innovation process. In one study it was found that oral channels were used to acquire necessary information 30% of the time. In another it was found that technologists use oral channels more than scientists. Something of the nature and importance of oral, face-to-face communications is obtained from a very interesting study of the use of various information channels in research and development projects, particularly under conditions of stress (Bodensteiner, 1967). The latter study compared the use of written, telephonic and face-to-face communication on several projects, particularly during periods of confusion or difficulty. It was found that in each instance of stress there was a buildup in the frequency of telephonic communication followed by a buildup in face-to-face communication until the problem was finished. Written communications were apparently used as a means of putting something on record, but not for the communication of currently needed information. A further observation made during the study was that where organizations had more face-to-face communications on a regular basis there appeared to be fewer periods of stress on their projects.
The results of the research on use of channels suggest that there are characteristic differences between channels that lead to the use of one, the face-to-face, more than another, telephone, and both of the foregoing far more than written communication for important or difficult communications. One important characteristic difference may be in terms of richness; that is the number of symbols available in each channel of communication. In the English language there are about 29 symbols available for use in the written language; 26 letters of the alphabet and three significant punctuation marks. In the spoken language there is something like 49 or 50 symbols available when one takes into account all the forms of inflection, hesitation, vocal urgency and the like. In face-to-face communications the number of symbols available include all of the vocal symbols plus body posture and facial expression. If one writes to a stranger "You are a pig!", he must be prepared to add a very lengthy explanation or be prepared for a very angry reaction. If one says the same words to a stranger on the telephone, but laughingly and with a warm voice, it is a completely different proposition. Finally, if one says the same thing to a man while looking at him, smiling, shrugging one's shoulders, it can become a completely acceptable expression.

It is, therefore, no surprise that difficult concepts, questions involving risk or trust or difficulty, and problems of every kind are far more efficiently communicated face-to-face than by phone, and far more efficiently by phone than by the written word. (For those who heard this address at the Conference it will become obvious that the written "translation" is far different than the spoken version.) When a man wants to order an item that is completely described in a catalogue, a one line telex is sufficient. The item number is sufficient description for the item. In most areas of the innovation process, however, we are dealing with a high degree of indeterminancy, and are forced, therefore, to resort to the richest form of communication available to avoid confusion and error. Similarly, when we are faced with situations of risk or trouble we resort to richer forms of communication in order to avoid misunderstandings that could lead to serious and unwanted consequences.

Found by accident — When asked where important information was obtained, from 18-20% of the respondents in studies of information sources of scientists replied that it

was "by accident". It was the book next to the book that they thought was wanted or an article in a journal next to the one that was sought. All of us have had this experience, and it has always seemed rather accidental. The persistence of the order of magnitude of such finds suggests that we are dealing with events that are not quite random. It suggests that the information obtaining process is not linear or as direct as is often assumed in the design of many retrieval systems. Furthermore it suggests that efforts to classify documents of various kinds in too specific and constrained a manner may rob us of the ability to benefit from that percentage of information that has seemingly been obtained by accident or by some process not yet fully understood.

My colleague, Engineer Achille Ferrari, raises an important point in criticism of some of the thinking that has been associated with information theory. He asks dialectically whether, perhaps, the information is in the noise, and that it may be an error to assume that noise is a degradation of signal. This is an interesting question since it suggests that when we have a specific message to transmit mechanically perhaps noise means loss of that signal. However, if we consider each human as someone with a thousand questions perhaps the noise provides an answer to one of the many questions that had not been the subject of the main transmission but valuable nevertheless (i.e. found by accident). If we take the view that each human is a multi-faceted organism dealing with more than one question at a time it is important to consider whether too clean and neat a mechanical system might not remove very important information from the system.

Situations — Situational factors have an effect on information behavior. The nature of the work, the organizational and physical work setting, and the kind of informational needs to be satisfied influence the way information is obtained and the kinds used. As has already been pointed out, research workers have a greater need for the information to be found in scientific journals than do technologists or managers. People with mission oriented problems use different materials and sources than do those with discipline oriented problems.

Whether an organization places a high value on the acquisition and use of knowledge has a distinct effect on the information behavior found within it. When I use the term "high value" I am not referring to the size of the library's budget or the number of people sent to conferences. I mean the kind of signals received by organization members with regards to information behavior. If you have managers who show their disapproval of reading at work, you will lave less reading. I have seen many a laboratory that had an elaborate library system, elaborate lists of people who should get a magazine next, but no one picks one up because the system is not meant to work that way. If the organization sends no one of any importance to technical meetings the signal is very clear to the rest of the people how valued technical meetings are in the organization. If they send only the new young people whom no one listens to, it tells you clearly what they think about the meeting, and going to meetings. This is also true of seminars.
Since I have been a Professor, I find it rather amusing that companies almost never send very important people to seminars, it tells you what they really think about education. I am not sure they are not right, but it is a measure of the reward system in a company, if it sends the junior people to seminars. Incidentally, if they gain anything in the course, no one of importance listens to them anyway. We did some studies of what happens to men who get masters degrees or doctors degrees under company sponsored programs in the United States, and we found that almost 100% of the time they leave the company after getting their degree.

Some studies by M.I.T. staff have reported on the effects of physical proximity on communication of work related material. It was found that the great majority of such communications took place between people whose desks were less than 30 meters apart. I have experimented with this idea when I was a manager of several research groups, and found that changing to location of a man shifts his work related conversations and the particular flow of information in the organization. It has been said that if you put a

research department next to a sales department it produces more products. If you put it near a University it produces more articles.

Differences among individuals — There are differences in capacity and capabilities among individuals that must be recognized. The capability and acquired knowledge you have makes a difference as to what information you perceive and use. We know that if you do not understand Swahili, it is useless to send you a message in Swahili. Further, we find some differences in information communication behavior that significantly affect the use of information in any organization. Allen has done the most significant work in identifying and studying what he calls, "the gatekeeper". We have done some work in the field and prefer to call the man "the high communicator".

The high-communicator is significantly different than others in the way he uses and communicates information. If you look at the reading done by people in a laboratory you will find many people who read two, three, four or five magazines, and then there is a man who reads 30 magazines. He tends to be a person to whom others go to for information and who constantly distributes information. The gatekeeper or high-communicator is one who acquires more written information than other people. Furthermore, he constantly receives information from a constant interchange with others. He is also one of the better workers in an organization. Thus, he is a man who reads a lot, does a lot, talks to a lot of people, inside and outside the organization, and has a great variety of sources of information; raising the information level of the entire organization.

Other aspects of individual differences in communication have been studied in the field of diffusion of innovation. For a long time many thought that younger people are more likely to know about an innovation and adapt it or, at least, to have more wide spread sources of information about it early. However, in their excellent book on communication and the diffusion of innovations, Rogers and Shoemaker (1971), reviewing many hundreds of empirical studies, indicate, on balance, the evidence is that there is no age bias in any direction. About 19% of the relevant studies say younger men use more information, 22% say older men use more information and the rest said no measurable difference. The general conclusion is that age is not particularly important. On the other hand, education is important; the more education the more likely he is to use many different sources of information and the more likely he is to adopt an innovation early.

It almost goes without saying that the motivation of the individual is a critical factor in the acquisition and utilization of information in the innovation process. You can design an information system that has a large quantity of information of high quality, and has all of the best procedures and mechanisms for obtaining, storing and distributing information. You can hire men of good education and men who are clearly high-communicators. However, in the end, if the people in the organization are negatively motivated all of your efforts will have been wasted. As the old saying goes "you can lead a horse to water, but you cannot make him drink." All the creativity exercises, all the education courses, all the management techniques fail if there as an organizational climate or a particular supervisory relationship, which makes the man not want to do something with the information. The trouble, or maybe the pleasure, of research on innovation is that we finally are faced with the situation of men who have choice. We cannot design the process so that it ignores man. Much as we might like to avoid man as a nuisance variable we have to come to grips with the fact that man is the generating resource and that he will not use the other resource, information, unless we motivate him well.

The Two-Person Information System

The one-person information system is the basic building block of an information system, and the two-persons information system is the basic building block of a communication system. Communications implies a source, or sender, and a receiver. We know something about two-person information-communication and behavior from a variety of literatures particularly those of the psychology of attitude change, the diffusion of innovation and the use of information by scientists and engineers.

Coding — Coding is essential to the two-person information-communication system's functioning. The two persons in the system must find a common code if they are to communicate, and perhaps the most important feature of the two person system is that both members activily participate in trying to find a common code. The extent to which the transmitter of a message is dependent on the active participation of the receiver can be illustrated by what I call the "Good Soldier Schweik" defense. Imagine trying to transmit a set of complicated instructions to a person who absolutely does not respond, who shows no facial expression, and who never lets you know whether or not be understands what you have said. A reverse example would be a situation where I tell you, "I was driving my car when another car suddenly crossed my path. Quickly I put on my.." You would instinctively supply a word to help complete the message.

Compare the feature of two way coding with a man-machine communication system in which the human is essentially dealing with a passive receiver. The burden is on the human to frame his question in the code of the machine. The man gets no cooperation, or very little cooperation. Sometimes a machine is programmed with very clever terms, but it does not actively participate in framing the question or finding the code.

Source characteristics — The data show that the characteristics of the source of a message have a definite influence on whether the receiver will change his attitude in a given direction or whether he will be more likely to adopt an innovation being urged on him. The authority, credibility, power, similarity and attractiveness of the source are among the characteristics that have been associated with the effectiveness of information transfer.
The more the source of a message has professional or social authority the more the listener or reader is likely to accept and use the information transmitted. Most technical readers quickly check the author's credentials and place of work and the publisher before deciding how to consider the material to be read. Advertisers have long known about the effectiveness of authority. Thus we find advertisements with a man in a white laboratory jackets, signifying science, urging us to use some headache powders.

The more credible the transmitting individual or organization the more likely is the receiver to accept the message. The more the transmitting person fits into the social-cultural framework of the receiver the more his message is acceptable and accepted. The more power the source has over the receiver, in the sense that he can apply sanctions, the more the message is accepted.

The more the source of a message is attractive to the receiver the more likely is the message to be heard and accepted. One of the characteristics that denotes the high-communicator is that the is socially liked, people go to him for information willingly. No matter how many university degrees a man has and no matter how extensive his personal data system, others will avoid him of they have to pay a psychological cost to get information from him. Furthermore, they will be disposed to find reasons to question or reject his information. Men will construct elaborate means for building circuits around the difficult and unlikeable "expert". It is not surprising that the high-communicator is found to be "easy" to approach, a pleasure to deal with.

The two-person bond — I would like to introduce a new concept at this point; that of the two-person bond. Two persons, communicating for the first time, generate a relationship that has a potential for becoming a continuing, value-laden bond between the two. The creation of the bond is dependent on the experience with the initial change and the potential value seen in the relationship. The disappearance or strengthening of the bond is dependent on the number, variety and value of subsequent exchanges. Where you find a growing and continuing relationship you will find a series of exchanges of information intertwined with social exchanges of many kinds; invitations to lecture, recommendations, consulting. Each exchange strengthens the bond. The longer the time between exchanges the weaker the bond, but another exchange (like the electronics "dither") brings the bond to high strength again. Interestingly, I find that the exchanges cannot

be on the basis of quid-pro-quo; that is, "I have given you something now you owe me something." Quid-pro-quo exchanges have a one transaction duration, and both parties are quit of each other after each exchange. The bond also carries with it validation of the information transmitted. You accept and trust information sent to you by someone with whom you have a bond. The older and richer the bond the more valid the information.

I have tried simple trials based on the idea that a bond can be strengthened, and become the conduit of highly valued information. I have mailed a paper that I have written to 40 people, randomly selected from my card file of names and addresses in an effort to see what reactions would occur, what pattern they might take. An interesting sequence of reactions followed. I immediately got back letters from some saying "Glad to hear from you," and telling me all about themselves. One or two even read the paper. I know this because by mistake I had sent the paper out without its bibliography, and only one or two noticed it. After a lag of some weeks suddenly I got back research reports of various kinds from people whose work was of interest to me. After some months I suddenly received a call from one of my addressees who asked if he could count on me in a large research project and urgently asking me for the bibliography from my report.

Another simple experiment is one that I recommend that you try. Take three names of people you know from your address list and call each of them. Tell them only that you had been thinking of them, or that you had decided to find out what they have been doing, or tell them some other such innocuous thing. Then note how much information you receive before the call is finished. It is an excercise in reinforcing the two-person bond that carries with it the most valued and useful information you can get.

Man-to-man versus man-machine — Comparing the two-person information system with the man-machine information system, it becomes easier to understand why there is so little use of the latter.

Two-Person System	Man-Machine System
active two way response	passive one way response
two way coding	one way coding
validation	no validation
rich language	non-rich language
personally rewarding in several dimensions	one dimensional reward

The Network

We are all members of information networks or what has been called "invisible colleges" (See Crane, 1972); that is social circles of a professional nature that play a very large role in information transmission. Our information networks are so much part of our everyday life that we are hardly aware of them. Yet they are so valuable to us that some of our most painful and embarrassing memories are those of situations in which we recommended someone into our network who did something bad or stupid or in bad taste.

The network has several important functions that directly or indirectly affect the information-behavior of its members. The network provides early and informal and rapid transmission of information that is generated within or enters any part of the network. The network provides its members with feedback without threat. The network establishes norms and values for its members and thus provides them with solidarity. As has already been pointed out the network also is a validating mechanism.

People within a science network know of research results something like two years before they are formally published. They have seen them or heard of them from colleagues who have asked them for feedback or merely been told of them informally over a drink at a meeting. After all, after an article is completed and submitted to a journal it takes 10 months to three years for it to be published. A book takes longer, and to find something in a library takes longer yet.

To illustrate how a network functions let me state arbitrarily that I can identify the precise information I want in any technical field using from three to five telephone calls. Take for example a question in a field I know nothing about such as the following: "What is known about the costs and benefits of alternate methods of psychotherapy?" Where to start? If I were to ask you how you would start, in almost every case you would answer that you know a Psychologist (or a friend who knows a psychologist), and you would suggest call him first. So we make our first call to Psychologist A, apologetically tell him of our problem, and incidentally tell him that you suggested calling him.

Having mentioned your name, Psychologist A, who knows you, takes me seriously, tells me he knows nothing of the subject and refers me to Professor B who really should know about the subject. I call B immediately telling him that A suggested that I call. He tells me of the work of C and D, telling me also that C's work is good and is more recent and that D is really quite bad and very dated. Furthermore, he tells me that I am using the wrong terms, and tells me the terms used in the field. I am now able to go to the library or to an information retrieval system and specify exactly what I want. I can repeat the process if I want a double check.

In the example I have found my way into a network starting from complete ignorance. I have used personal references to get from point to point. I have been taught the proper coding used in the network. I have been given validated information which no library does, having been told whose work is good and which work is old. I have not become a member of the network (that would have to come about as a result of my work and personal sponsorship), but I have used it effectively for a single information trace. I could not use it again and again in the same way without becoming a contributor, for it has been found that members of a network who only take from it without contributing are dropped from the network.

The high communicator and the network — The structure of networks in science might be described as a hierarchy of networks in which the lowest level is a high communicator (or gatekeeper) surrounded by a group, feeding into a higher level network of high communicators. The high-communicator actively applies "dither" to the networks, revitalizing the two-person bonds in the system. He is the man who thrusts information upon you, eagerly telling you about work in another field that is relevant to what you are doing.

The high-communicator plays a vital link-up function. He ties his organization into a wider world of information. He brings with him links to an extended family of networks thereby substantially raising the information potential of the organization. Further, he is a pattern recognizer, seeing relationships between otherwise unconnected bits of information, an important creativity function. One of my students (Holland, 1968) measured this characteristic by administering a psychological test, the Remote Association Test of Mednick to a number of high communicators he had identified in a variety of laboratories and university departments finding that the high communicators had significantly high scores on the test.

Implications for Management

Examining the innovation process, the role of information in the process, and the empirical evidence concerning information communication behavior that is presently available, some possibly useful implications for management are evident. For one thing, it becomes evident that national efforts and investments in large formal scientific information systems will not result in more innovations moving through the system more

rapidly. The science research sub-system is a rather self contained organism, consuming its own product. It has little connection with other parts of the innovation process, and, by the very nature of its norms and values, there is little hope that it will become more connected with the rest of the process.

The outputs of the science system are research results and theories in the form of refereed publications in scientific journals. The man who publishes first gets the Nobel prize, and in American universities the man who publishes most gets promoted. In many fields if a submitted article is accepted, the author pays page charges of about $ 50 a page; thus, the only market for an article is the author. An article is consumed by others in the production of further articles. When you consider that in the United States, alone, we have 500,000 professors you can well understand the forces driving us to a so called "information explosion".

An important gap — An important gap in our knowledge of information-communication behavior exists in the knowledge transformation subsystem. We have insufficient data on how technologists and engineers actually get and use information. We know very little about how information flows or, better, "trickles" from the knowledge production subsystem into the knowledge transformation system. Filling this knowledge gap I believe is important to all our efforts to get a larger return on the very large investments we have made and continue to make in research and development.

Since there is little evidence that engineers and technologists in the knowledge transformation subsystem read or use the outputs of the science subsystem except what they have learned at the university 10-15 years before. This suggests that we might try to assure that we transfer more and more useful research results to our students when they are in the university since it is probably their last direct contact with the science world.

At the micro level several management implications become evident:

1. Identify and hire high communicators
2. Consciously provide the high communicator with all the information he asks for
3. Consciously arrange for the physical proximity of the people who should be communicating with each other
4. Formally design situations and contexts that will encourage informal exchange among people within the organization and with people outside the organization
5. Provide incentives to elicit the kinds of information behavior you desire
6. Generate communication flow chains that increase the flow of information to those subsequent sources that have authority and credibility and that are attractive to others so that in the subsequent flow the information will have a higher likelihood of being used

References

The research findings discussed in the body of this paper are based on a very large number of sources that are to be found in the growing body of literature on communications among scientists and engineers. I refer the reader to the excellent annual reviews edited by Cuadra and published by Encyclopedia Britannica.

A few of the sources that have been referred to at greater length are given below:

Allen, Thomas J.,	"Roles in Communication Networks", in Nelson, C. E. and Pollock, D. K. (eds), Communication Among Scientists and Engineers, Heath Lexington Books.
Crane, Diana,	Invisible Colleges, University of Chicago Press, 1972.
Holland, W. E.,	Intra and Inter-Organizational Communications Behavior of Scientists and Engineers with High Information Potential, Ph. D. dissertation, University of Texas, Austin, Texas 1970.
Pelz, Donald C. and Frank M. Andrews,	Scientists in Organizations, John Wiley and Sons, Inc., New York, N. Y., 1966.

DISCUSSION

Question

In our firm we have discussed the preference for written information or personal contacts quite often. Of course we know about the American findings that in the U.S.A. almost nobody uses written information. But I still think that there may be a difference between your country and Europe. Perhaps Europeans turn to written information more easily than Americans. As you have lived in the U.S.A. and in Europe, you may be able to settle this question for me.

Answer

In the main you are right, but it is easy to exaggerate the differences. When my colleagues in the States maintain that the situation is very different in Europe, I kindly point out to them that we do live on the same planet and that most Americans come from Europe anyhow. But it is true that there are some basic differences in communication and information exchange on the two sides of the Atlantic. If I may overgeneralize, it is easier to get informal information in the US than in Europe. One reason for it is that we have a more mobile society. Managers don't fool themselves that there is any economic value in secrecy, they may be working in the other company next month. So they brag to each other about their methods, something that is done to a far lesser extent in Europe.

Remark

I would like to take issue with Professor Shapero on this point. Perhaps I may start by reminding you of your statement about the danger of drawing one-point curves, based on the experience of one person. I suggest that now you are doing something similar, which, however, is not necessarily wrong as we all speak from experience. My experience of my American colleagues, with whom we have many useful and pleasant contacts, is that their use of written information is no less than ours, and that our use of verbal inter-personal contacts is no less than theirs. This leads me to the last issue you raised on the scientific literature. You may, I think, be drawing on your own experience again. But the basic scientific literature very frequently supplies a back-up in background information, and that is very important.

Answer

Well, this gives me the opportunity to clear up some misunderstandings. I didn't give you my opinion on the preference for verbal information, I spoke from a body of literature. There have been done scores of user studies by now, and they all give very consistently that the literature is not used very much. This accords with my own experience and satisfies my prejudices, but I did not draw a one-point curve here.
As to the scientific literature, I did not mean to convey the impression that it is not used at all. That would be untrue; it is used, but not to a large extent. In many cases, a man who wants to know something will not look it up himself, he will ask the high communicator. It has been stressed again and again that this is an unsatisfactory situation; the literature is there to be used and it isn't. That is why I said that the information leaks rather than flows. And I have the impression, but I cannot cite any study on it, that one of the more important leaks is the popular literature. There, I think, managers find the connection between the scientific possibilities and the satisfaction of a need. If my impression is correct, it means that the importance of the popular literature is rather underestimated at the moment.

Remark

(Holt) I would like to add that we did a similar study in Sweden, where we had one

group of engineers and another of R & D people. For the engineering group the results were practically the same as in the United States, but for the R & D group the use of the literature was significantly higher.

Question

I do agree that big firms have a problem here. But I want to stress that meetings of this disciplines. Now we have to assume that these people meet randomly and in a large firm the chances that someone in need of information will meet the right person at the right moment, become pretty small. So a large firm has something to do about this, it has to be organized somehow. Do you agree and do you have some suggestions ?

Answer

I do agree that big firms have a problem here. But I want to stress that meeting of this kind should stay informal, this is very important. Now I do not see any way to organize informality, that is a contradiction in terms. You can create the right conditions for informal meetings between people, but you cannot organize it. Of course you can do many things to stimulate informal contacts. You can transfer people to another town or another country, you can arrange for your people in the field to visit the laboratories, production department and so on, and ask them to tell everyone who wants to listen about their problems. And you can ask a research man to visit a customer. That is quite an experience for both, and if all goes well, they will soon start to educate each other quite wonderfully.